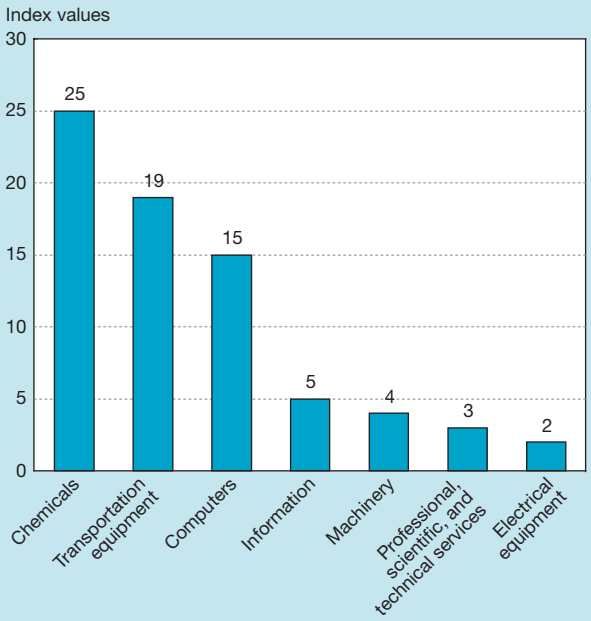
and services sides, respectively, of information technology activity. Remarkably, the share of information services in R&D spending abroad (8.3 percent) is five times larger than that industry's foreign R&D share (1.5 percent) in 1998. The opposite is true for computer and electronic products. The computer industry accounts for 20 percent of total foreign R&D in the United States, twice as large as its 10 percent share in R&D funds spent abroad. However, more data based on the newly established NAICS classification system would be needed over time to form a more accurate picture of the R&D flows in these two components of IT R&D.

Another measure of the degree of globalization of R&D activity is obtained by combining these R&D spending shares. Specifically, the Industrial Globalization R&D (IGRD) index is defined as the average of foreign and overseas R&D spending shares for a given industry.[84] This average indicates how open an industrial innovation system is to R&D flows, not unlike the sum of exports and imports, which quantifies the openness of national economies to the flow of goods. By this measure, chemical manufacturing in the U.S. exhibit the highest degree of internationalization with an IGRD index of 25, followed by transportation equipment (19), and computer manufacturing (15). (See figure 4-40.)

Several implications may be drawn from this indicator. An industry with a high IGRD index may be less constrained by national R&D expenditure trends. Furthermore, such an industry is more likely to have the institutional setup required to take advantage of technological opportunities elsewhere. The index could be used in conjunction with other international S&T indicators discussed in this volume, including bibliometric indicators, foreign-origin patents, international alliances and R&D facilities, and high-technology trade.[85]

[84]In principle, the IGRD index has a range of [0, 100]. However, reasonable index values for R&D-intensive industries in advanced economies are not likely to exceed or even be close to 50.

Figure 4-40.
Industrial Globalization R&D index for selected U.S. industries



NOTE: The Industrial Globalization R&D (IGRD) index is the average of foreign and overseas R&D spending shares for a given industry.

See appendix table 4-52. *Science & Engineering Indicators – 2002*

Conclusion

A resurgence in R&D investment in the United States in the mid-1990s has continued through to the beginning of 2000. A prosperous economy invigorated companies in both the manufacturing and service sectors, enabling them to allocate more resources toward the discovery of new knowledge and the application of that knowledge toward the development of new products, processes, and services. An upsurge in innovation is further contributing to a buoyant economy.

At the same time that the private sector's role in maintaining the health of U.S. R&D enterprise has been expanding, the Federal Government's contribution has been receding, as the Federal share has become less prominent in both the funding and the performance of R&D. Similar developments have been seen in many countries throughout the world. As a result of these two divergent funding trends in the United States, the composition of the nation's R&D investment is slowly shifting. For example, a growing percentage of the nation's R&D total has been directed toward nondefense activities.

Concurrent with these broad patterns of change, the locus of R&D activities is also shifting as a reflection of broad technological changes and new scientific research opportunities. For example, a growing amount of industrial R&D is now undertaken in services (versus manufacturing) industries, and much of the industry R&D growth has been in biotechnology and information technology. Reflecting the political reality of tremendous increases in research funding for NIH relative to other Federal agencies, the composition of these Federal funds has shifted markedly toward the life sciences during the past several years. Whereas industry has focused its R&D on new product development, the Federal Government historically has been the primary funding source for basic research activities.

As part of the changing composition of R&D activities, the organizational process of conducting R&D also has undergone substantial change. Greater reliance is being placed on the academic research community, and all sectors have expanded their participation in a variety of domestic and international partnerships both within and across sectors. The rapid rise in global R&D investments is evident from the expansion of industry's overseas R&D spending and the even more rapid rise in foreign firms' R&D spending in the United States. These domestic and foreign collaborations permit performers to pool and leverage resources, reduce costs, and share the risks associated with research activities. In addition, such alliances and international investments open a host of new scientific opportuni-

[85]See earlier sections in this chapter, as well as chapters 5 and 6 in this volume.

ties for R&D performers that undoubtedly will continue to redefine the R&D enterprise into the future.

Each of these developments creates further challenges in terms of data measurement and indicator improvement. Indeed, there are a number of specific areas of interest that could benefit from expanded data collections and analyses (National Research Council, 2000). Most notably, better information is needed on structural changes in industrial R&D (including research on the nature of R&D in the service sector and obtaining finer detail by industrial classification and geographic location). More extensive data could improve our understanding of the relationship between R&D and innovation to address the manner in which science and technology are transferred among firms and transformed into new processes and products. Fuller investigations and tracking of the apparent increase in the web of partnerships among firms, universities, and Federal agencies and laboratories in conducting R&D are warranted, as is more research on the extent and role of multidisciplinary research in science and engineering. Both of these latter topics, research that involves multiple partners and multiple fields, illustrate directly the growing complexities that characterize the R&D enterprise.

Selected Bibliography

Adams, J.D., E.P. Chiang, and K. Starkey. 2001. "Industry-University Cooperative Research Centers." *Journal of Technology Transfer*, Vol. 26, No. 1/2: 73–86.

American Association for the Advancement of Science (AAAS) and Centre for Science Research and Statistics (CSRS). 2001. *Comparative Study of National R&D Policy and R&D Data Systems in the United States and Russia* (draft). Washington, DC.

Arora, A., A. Fosfuri, and A. Gambardella. 2000. *Markets for Technology and Their Implications for Corporate Strategy.* Pittsburgh, PA: Carnegie Mellon University, Heinz School of Public Policy and Management. Mimeographed.

Battelle Memorial Institute and the State Science and Technology Institute. 1998. *Survey of State Research and Development Expenditures: FY 1995.* Columbus, OH.

Behrens, T.R., and D.O. Gray. 2001. "Unintended Consequences of Cooperative Research: Impact of Industry Sponsorship on Climate for Academic Freedom and Other Graduate Student Outcome." *Research Policy* 30: 179–199.

Board on Science, Technology, and Economic Policy, National Research Council. 1999. *Securing America's Industrial Strength.* Washington, DC: National Academy Press.

Boesman, W. 1994. *Big Science and Technology Projects: Analysis of 30 Selected U.S. Government Projects.* 94–687 SPR. Washington, DC: Congressional Research Service.

Bozeman, B. 2000. "Technology Transfer and Public Policy: A Review of Research and Theory." *Research Policy* 29: 627–55.

Brod, A, and A.N. Link. 2001. *Trends in Cooperative Research Activity.* In M.P. Feldman and A. Link, eds., *Technology Policy for the Knowledge-Based Economy*. Boston: Kluwer Academic Press.

Brooks, H., and L.P. Randazzese. 1998. "University-Industry Relations: The Next Four Years and Beyond." In L.M. Branscomb and J.H. Keller, eds., *Investing in Innovation: Creating a Research and Innovation Policy That Works.* Cambridge, MA: MIT Press.

Bush, V. 1945. *Science—The Endless Frontier: A Report to the President on a Program for Postwar Scientific Research.* Reprinted 1990. Washington, DC: National Science Foundation.

Centre for Science Research and Statistics (CSRS). 2001. *Russian Science and Technology at a Glance: 2000.* Moscow.

Cline, L., and G. Gibbs. 1997. *Re-negotiation of the International Space Station Agreements: 1993–97.* Paris: International Astronautical Federation.

Cohen, W.M., R. Florida, L.P. Randazzese, and J. Walsh. 1998. "Industry and the Academy: Uneasy Partners in the Cause of Technological Advance." In R. Noll, ed., *Challenges to Research Universities.* Washington, DC: Brookings Institution Press.

Committee on Science, Engineering, and Public Policy (COSEPUP). 1999. *Evaluating Federal Research Programs: Research and the Government Performance and Results Act.* Washington, DC: National Academy Press.

Cordes, J.J., H. Hertzfeld, and N.S. Vonortas. 1999. *A Survey of High Technology Firms.* Washington, DC: U.S. Small Business Administration.

Council on Competitiveness. 1996. *Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness.* Washington, DC.

———. 1998. *The New Challenge to America's Prosperity: Findings From the Innovation Index.* Washington, DC.

Dalton, D.H., M.G. Serapio, and P.G. Yoshida. 1999. *Globalizing Industrial Research and Development.* Washington, DC: U.S. Department of Commerce, Office of Technology Policy.

Davey, M., and R. Rowberg. 2000. *Challenges in Collecting and Reporting Federal Research and Development Data.* Washington, DC: Congressional Research Service.

David, P.A., B.H. Hall, and A.A. Toole. 2000. "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence." *Research Policy* 29: 497–529.

Eurostat. 2001. *Statistics on Science and Technology in Europe: Data 1985–99.* Luxembourg: European Communities.

Executive Office of the President, Office of Science and Technology Policy, National Science and Technology Council, Committee on Environment and Natural Resources, Subcommittee on Global Change Research. 2001. "Our Changing Planet: The FY2001 U.S. Global Change Research Program: A Supplement to the President's Fiscal Year 2001 Budget." Available at <http://www.usgcrp.gov/>.

Feldman, M.P., I. Feller, J.E.L. Bercovitz, and R.M. Burton. 2001. "Understanding Evolving University-Industry Relationships." In M.P. Feldman and A. Link, eds., *Technology Policy for the Knowledge-Based Economy.* Boston: Kluver Academic Press.